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INFLUENCE OF SPACE TECHNOLOGY ON HEMISPHERIC DEFENSE: AN INTER-AMERICAN DEFENSE COLLEGE LECTURE

R. W. Buchheim

PREPARED FOR:
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SANTA MONICA • CALIFORNIA

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1700 MAIN ST • SANTA MONICA • CALIFORNIA

PREFACE

This is the text of a lecture given in January, 1963, at the Inter-American Defense College. The lecture was prepared at the invitation of the Director, Major General Thomas F. Van Natta. The topic was assigned in keeping with the purpose of the college, which is to "conduct courses of study on the inter-American system and the military, economic, political and social factors that constitute essential components of inter-American defense in order to enhance the preparation of selected personnel of the armed forces of the American Republics for undertakings of international cooperation."

This is being published in its present form to make it available to a wider audience.

SUMMARY

The most substantial immediate contribution of space technology to hemisphere security is through application to the U.S. strategic deterrent force. In relation to national or regional security in the near future, the most important applications of rocket vehicles--the fundamental element of space technology--will continue to be long-range ballistic missiles and satellite launchings.

Progress in the ballistic-missile arts has increased interest in space systems for comprehensive surveillance and prompt communications. The speed with which important events may develop places a great premium on rapid, reliable, and clear communications over long distances. Communication satellites appear to be capable of overcoming the limitations of conventional radio and cable systems, which are vulnerable to degradation or disruption by nature or unfriendly action. Before an effective regional or global communication network can be realized, however, there are time-consuming problems to be solved, concerning not only satellite design and reliability but international agreement on technical and financial details.

Observation satellites are of interest for defense purposes because they can cover very large areas rapidly. Photography from satellites, with the possibility of a large view in fine detail, can also be useful for such purposes as mapping, geological surveys, petroleum exploration, and agricultural analysis.

Meteorological satellites, which have proved to be entirely practical, can be used to attain two objectives: the gathering of data of immediate practical usefulness (e.g., storm detection), and the

gathering of data for long-term meteorological research, leading to accurate prediction, and perhaps modification, of weather. World-wide coverage from meteorological satellites could result in sharp improvements in weather services in the southern part of the Americas, where there is presently little opportunity for receiving good meteorological data.

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I. INTRODUCTION

It is a great honor and pleasure to appear before this challenging audience and participate in the first term of operation of this important new institution.

At the outset I want to thank General Van Natta for inviting me to prepare this talk, because it has introduced me to some very interesting new lines of thinking--space technology is a subject familiar to me in my daily affairs, hemisphere security is not; and the relationship between the two is something I might never have been led to explore specifically if left to my own devices. Having been confronted with the notion of a relationship through the initiative of this college, I have found the exploration most interesting. It is my definite impression now that there is an important set of relationships between space technology and hemisphere defense--so much so that I would like to be able to take the ideas assembled so far as just a start in developing a fuller understanding of this interesting area. It is my hope today that I can respond to your initiative well enough to stimulate some of you to also consider the matter further. Your comments and counsel, now and at any later time, will be most welcome.

II. SPACE TECHNOLOGY AND STRATEGIC DETERRENT

As a brief definition: In using the term space technology I will be speaking about that body of related scientific, engineering, and industrial information, equipment and operations that are employed in the design, construction, and operation of rocket-propelled vehicles intended for flight outside the earth's atmosphere during all or part of their flight time. The fundamental element of space technology is the rocket vehicle, and it may be used for a wide variety of functions including use as a long-range ballistic missile, placement of a satellite into orbit around the earth, launching a set of instruments to the moon or planets, etc.

For operations that have a reasonably clear bearing on national or regional security, the rocket-vehicle applications of most importance in the near future are ballistic missiles and satellite launchings.

The most substantial immediate contribution of space technology to hemisphere security is surely through application to the U.S. strategic deterrent force. The rocket vehicle is the vital core of space technology, and such vehicles are entering the deterrent force in the form of long-range ballistic missiles in increasing numbers. In addition to providing the basis for strike elements, space technology also offers the possibility of providing observation elements through the installation of cameras and other equipment in satellites, thus suggesting opportunities for timely warning of an approaching large-scale military threat.

Such very important products of space technology can be of major value in implementing the U.S. objective of preventing military

aggression against itself and its allies. The whole purpose of the deterrent force is to effectively suppress the threat of large-scale warfare so that peaceful activities may flourish. The climate of co-operation and agreement in this hemisphere established by the Organization of American States and its underlying history is one of the most important facts that gives meaning to this strategic force. Therefore, the U.S. strategic force, supported by space technology, and hemisphere security and progress are intimately related as means and ends. The deterrent force provides assurance that the nations of this hemisphere <u>can</u> pursue their individual and joint goals in peace and security. The O.A.S. instruments are a formalization of firm assurances that progressive and constructive programs of advancement <u>will</u> be planned and carried out.

The deployment of a strategic deterrent is presently a unique contribution of the United States to hemisphere security. As the future unfolds, perhaps other American republics may become more actively involved in ways not readily predictable now. The uncertain course of development in space technology is itself an element of change in these matters.

As a point of possible relevance here we might note that characteristics of rocket vehicles already raise the possibility of various directions of approach to the United States from the Eastern Hemisphere. It has been familiar to think in terms of routes over the Arctic regions between the Soviet Union and the United States. These routes are clearly indicated for airplane operation, and travel between these

regions by other air routes would involve enormous difficulties. As a result, a considerable complex of warning systems has been put into operation across the northern regions of the Western Hemisphere. Equipment for warning of ballistic-missile attack has also been installed to cover northern routes. However, as has been repeatedly stated by Mr. Khrushchev, the nature of rocket vehicles is such that only moderate difficulties are involved in extension of the range of a missile from, say, 6000 miles to 20,000 miles; thus, attack from the Soviet Union on the United States could also be reasonably executed over Antarctic routes as well. Therefore, for the future, one might speculate about defense installations in the more southerly regions of the hemisphere.

In the last few months we have witnessed in a very direct way an interaction of space technology and hemisphere defense; that is, the temporary installation of Soviet ballistic missiles in Cuba. This intrusion with rocket vehicles of offensive character was dealt with through use of the mechanisms of the Organization of American States and on the foundation of U.S. strategic power. The need to guard against repetition of such an intrusion strongly suggests need for ready means of surveillance and prompt communications within the hemisphere. Space technology can be usefully considered for meeting these needs. Interest in space systems for surveillance and communications is increased by a recognition that progress in the ballistic-missile arts can lead to the existence of offensive weapons that could be intruded into the hemisphere in very short periods of time with little obvious warning.

III. COMMUNICATION SATELLITES

One of the chief features of the present hemisphere security system is firm agreement to consult on matters affecting the common security. The speed with which important events may develop under modern circumstances places a great premium on rapid, reliable, and clear communications over long distances. This emphasis suggests the desirability of examining the possibilities of communication satellites for hemispheric-security purposes.

Presumably a communication system for consultation on security matters should display many of the essential features of a good communication system for military operations; and both functions, consultation and operational communications, should be available anyway.

I would like, therefore, to briefly summarize some of the considerations that have led to exploration of satellite systems as alternatives or supplements to the techniques presently utilized for long-range military communications:

Effective military operations have always depended heavily upon the most rapid and reliable communication systems available. Because of the nature of modern weapons, this requirement is greater today than ever before. Improved communications are needed in order to assure control, command, and appropriate response of widely dispersed military forces and weapon systems. The capabilities of conventional communications techniques are limited, while at the same time security interests extending over large areas place an increasing burden upon them.

At the present time, long-range military communications are handled primarily by high-frequency radio links and undersea cables.

In the case of radio communications, the useful region in the high-frequency spectrum is already severely crowded. Furthermore, reception of radio signals is frequently unreliable because of noise interference and propagation disturbances.

More important from a military standpoint, radio transmissions are susceptible to jamming.

Finally, high-frequency radio circuits can be seriously affected, sometimes entirely blacked out, by nuclear explosions high in the atmosphere and by natural phenomena such as sunspot activity. The mid-1960's are predicted as a period during which many of the higher-frequency radio circuits will be often unusable due to the character of solar activity which will take place during that period of the 11-year sunspot cycle.

Submarine cables are quite expensive to install and are limited in capacity.

From a military standpoint, a significant shortcoming of cables is their susceptibility to sabotage or destruction by an enemy. Once cut or destroyed, cables are not quickly repaired or replaced, and long periods without service can result.

Also, cables cannot be laid quickly to service new locations that may present an unexpected need for quick establishment of a new communications terminal.

Thus, modern military problems render conventional radio and cable systems increasingly more vulnerable to degradation or disruption by nature or unfriendly action, and current capabilities for transmission of military messages over extended distances may become a serious weakness in the system of hemisphere security.

Communication-satellite systems potentially offer the capability of overcoming many of the limitations of present facilities and theoretically will provide increased range, higher reliability, and greater flexibility and capacity for military communications. Among other things, satellite systems hold forth the possibility of bringing prompt communications service to areas that may suddenly take on important security significance.

The view that communication-satellite systems offer substantial promise for the future in military communications is reinforced somewhat by considering a trend of uses within current systems. These current systems are chiefly high-frequency radio and undersea cables. Of these two, the cables are more reliable in the sense of freedom from interference and propagation problems and offer much higher quality and clarity of transmission. As more cable capacity has been laid there has been a definite increase in the use of this medium of communication in preference to radio for military traffic. It is expected that satellite communication systems can be made to offer a quality of transmission as good as that of cables and, in addition, also allow more rapid institution of service to more locations. Thus, it can be argued that the factors causing the present trend from radio to cable use will also lead us to favor satellite systems, and, furthermore, that satellite systems offer advantages relative to cables for military purposes.

In a broader view of hemisphere welfare we must, of course, also recognize the importance of communications to commerce and cultural interaction. Experience so far clearly indicates that availability of more and better communications capacity tends to increase usage. In

recent years we find that simply substituting cable-quality service for high-frequency radio service tends to double the number of telephone minutes.

For example, message minutes doubled within two or three weeks after the cable between Bermuda and the United States was opened for service, although no publicity was given to the new cable at the time. In August 1962, two cable-quality circuits were provided between the United States and Spain, where previously the only service had been by high-frequency radio; again, there was no publicity, but within a month the message minutes had doubled. By and large, to almost all points, about half the overseas telephone calls are business calls, and about half are social calls. It is not unlikely that the business community is responsible for most, if not all, of the immediate increase in telephone conversations following the introduction of cables--news of the better quality of service would travel rapidly among the business users and more slowly among the social users. If this is right, it follows that the business community has tripled its use of overseas circuits, following the introduction of cable-quality service to Bermuda and Spain.

If cost and continuity of service could be ignored, it would be possible to go ahead at once with the procurement and launching of communication satellites and the establishment of long-range satellite communication links. Communication links to and from spacecraft have already been employed successfully in a large number of cases; and five U.S. satellites have been placed in orbit with the specific purpose of providing experimental point-to-point communications between locations on the earth's surface. These communication satellites have,

however, all been strictly experimental in purpose. The four active satellites died or suffered malfunctions and interrupted service in a matter of days or months.

In addition to remaining problems of satellite design and reliability there may be time-consuming problems in carefully constructing the necessary international agreements that must support an effective regional or global network.

First, there are problems connected with the international allocation of the radio-frequency spectrum. The allocation of frequency bands for operational communication-satellite systems will be governed by international agreement. The subject will be considered at the Extraordinary Administrative Radio Conference for Space Communication to be held in Geneva in October 1963. There is general agreement that on technical grounds frequencies between 1000 and 10,000 megacycles per second are most advantageous for communication-satellite systems for the foreseeable future.

World-wide communications facilities have been rapidly expanding, and if communication-satellite services are to grow according to the present views of their potentialities, it is important to allocate adequate spectrum space to meet long-term needs.

A second type of international problem concerns the general nature and characteristics of a satellite communication system intended to serve the needs of many countries. There are many competing views favoring various kinds of systems that must be brought to a productive compromise. Differences exist on many aspects, technical and legal.

There are specific problems requiring negotiation with corporations and agencies of governments, particularly the governments of countries

in which terminal stations would be located. While informal bilateral agreements for experimental stations may not be difficult to arrange, on an interim basis (some already exist), the more permanent and detailed technical and financial agreements needed to support a full-time regional or global service may require considerable effort to construct.

The role of the satellite itself in the communications link is the basis of a fundamental distinction. If the satellite receives radio signals from one station and merely reflects them back toward other stations, its role is passive, and the satellite and system are said to be "passive." An "active" satellite, on the other hand, receives, amplifies, and sends radio signals; and for this purpose it possesses a more or less complex electronic mechanism and possibly other components. Although the Echo passive satellite was successful in several respects, it is generally assumed that the future lies with the active systems. In the present state of knowledge the issue should not be foreclosed, but the remainder of my remarks will be concerned with active systems.

While any number of orbital configurations can be imagined, from the point of view of terminal-station design the important distinction is between "stationary" satellites and other satellites. Stationary satellites occupy a fixed point in the sky as seen from a particular ground station, and the station antennas can therefore be designed for fixed or slowly adjusted mounts. Satellites in any but stationary types of orbits move rather rapidly from horizon to horizon as seen from a ground station, and for these the station antennas must be provided with rapidly movable mounts and designed for tracking the satellites across the sky. Other things being equal, tracking antennas and

their associated equipment are more costly to construct and install than fixed antennas. But tracking antennas have the advantage that they can be used for all types of satellites, including stationary satellites. They are thus more flexible in use, and this flexibility may be worth paying for in the early years of communication-satellite development.

The orbit for stationary satellites is uniquely defined: It lies in the earth's equatorial plane at an altitude (19,300 nautical miles) such that the satellite moves with the same angular speed as the earth's surface and thus makes one revolution toward the east about the earth's axis every 24 hours. Compared with most alternatives, this is a high-altitude orbit, and as a stationary satellite must be placed in orbit with a high degree of accuracy with respect to altitude, speed, and direction, a large rocket vehicle and first-class guidance are required. Moreover, to overcome the effects of natural perturbations, location-keeping devices are required on board stationary satellites, and these devices increase satellite weight and complexity. No communication satellite has yet been placed in stationary orbit.

For nonstationary satellites, many different orbital configurations have been proposed. In general these provide in one way or another for a succession of satellites to pass through the space simultaneously visible from each of two ground stations, so that there will almost always be at least one satellite that is "mutually visible" from the two stations and therefore available to relay signals from one to the other.

Proposals for nonstationary satellite systems usually provide for orbital altitudes considerably lower than the 19,300 nautical miles required for stationary satellites and can permit greater margins for

error in their orbital placement. Thus, they make less rigorous demands on rocket and guidance technology and cost less per pound of satellite placed in orbit.

Generally speaking, a satellite can provide service to a smaller area on the ground when it is in a low orbit than when it is at high altitudes. In all nonstationary systems, therefore, a number of satellites arranged to appear in sequence are required to perform the functions of a single, functioning, stationary satellite. As a nonstationary satellite moves away and ceases to be visible from a given pair of terminal stations, another satellite must come over to replace it.

The number of satellites required in nonstationary systems depends upon several factors:

- o The area of coverage from a single satellite, which in turn depends mainly on the orbital altitude;
- o The configuration of the orbits; for example, whether they are equatorial or polar;
- o The distribution of satellites within the orbits; that is, whether they are random or controlled by on-board, position-keeping devices; and
- o The continuity of service or percentage of in-service time required.

In general, it can be said that the number of nonstationary satellites required varies within wide limits, depending on the characteristics of the system, and may range from four to forty or more satellites.

Within the area of its coverage, a single stationary satellite can provide continuous service between any two stations; and, due to its high altitude, a single stationary satellite can provide service over a

rather large region--a single one could serve almost all of the Western Hemisphere, and three could serve a world-wide network of stations covering the whole globe except for the polar regions. This ideal statement must, however, be moderated a bit by a recognition of the fact that satellites can cease to function. Satellite reliability is the key technological problem in this field at present. For stationary satellites, it is also the key to the practical number of satellites actually required in orbit. If only a single stationary satellite is in place and it stops functioning, service comes to an end throughout the whole region. As all the steps necessary to put a replacement in orbit could take days to accomplish, a failure of this kind would impose undesirably long (although perhaps infrequent) discontinuities in service.

For this reason, nearly every proposed stationary system provides for spare satellites to be constantly in place in orbit. The number of spares in orbit varies with the system designer's estimate of satellite lifetimes and an assessment of the standard of continuity required. Thus, depending on satellite technology, it would appear that a system for the Western Hemisphere using stationary satellites would require one satellite in service plus a few orbiting spares.

For the nonstationary system, the problem of service continuity is not a matter of long and sudden outages; it is a question of short delays occurring predictably several times a day. These delays would be not unlike the delays encountered in making a radiotelephone call or in placing a transatlantic telephone call during a busy period.

Another difference between stationary and nonstationary systems is that in the nonstationary system the same number of satellites will

serve both regional and global networks. That is, with nonstationary satellites, a regional network can be expanded to encompass the globe without requiring more satellites in orbit; all that is needed is the installation of additional ground stations.

The Atlantic region is already provided with a number of satellite-terminal stations. These were built primarily for testing experimental satellites, but the ground equipment needed for satellite communications is technologically straightforward in character, and the experimental stations should be convertible for routine operational use without much difficulty. All these existing stations incorporate tracking antennas, and they could therefore be used with either stationary or nonstationary satellite systems.

There are now two stations on the eastern seaboard of the United States (one in Maine and one in New Jersey), four in Western Europe (one each in England, France, West Germany, and Italy), and one in South America (at Rio de Janeiro). These stations could constitute a suitable nucleus for commercial use in the Atlantic region, although it would be preferable to also have one of the U.S. stations farther south, possibly in Florida. In Europe perhaps three stations would be enough at present, and at least one more would be desirable in South America. To bring it into operation the main thing needed is the orbiting elements of the system--the communication satellites themselves.

Clearly the field presents a wide choice of possible communications-satellite systems, differing in satellite design, orbital configuration, terminal-station design, network location, and other respects. In selecting one particular system and placing it in operation, one would ideally choose the system that could provide the required service at the

lowest cost. But both the nature of the required service and the magnitude of the system cost are subject to very large uncertainties. The difficulty is compounded because at the present time experience is limited to experimentation with only a very small number of satellites.

Comparison clearly indicates that the nonstationary system makes its greatest demands on the ground equipment, while the stationary system makes its greatest demands on the orbiting equipment. It is for this reason that most engineers agree that a nonstationary system could be placed in operation at an earlier date than a stationary system. There is wide disagreement, however, about the number of years separating the operational dates of the two systems. The estimates vary depending on one's judgment concerning the difficulty of achieving a reliable stationary satellite with all its necessarily complicated subsystems.

The Telstar and Relay designs could be used as the basis for a nonstationary system. The first stationary satellite design of interest for commercial purposes is the advanced Syncom satellite, now under limited development. The first launching of this satellite could be reasonably programmed for late 1964 or early 1965, assuming that the soundness of the basic design is demonstrated before then.

There is general agreement that in the long run the stationary-satellite concept offers the greatest promise and growth potential.

Much controversy can arise if one assumes that an either-or choice must be made now or in the near future, that is, in the absence of really adequate information. It is, therefore, quite helpful to recognize that perhaps no either-or choice is really required by technological considerations, for existing ground stations (and any future

stations intended for use with nonstationary satellites) could be employed in either system. Choice is foreclosed only if the first generation of operational ground stations is limited to use with stationary satellites.

An entire communication system does not come into existence overnight; it evolves. Adopting the evolutionary approach, and assuming that an early operational date is desired, it appears that it might be worthwhile to initiate limited regional operations with relatively simple nonstationary satellites and existing launch vehicles, to gather valuable operational experience, reveal unanticipated problem areas, and provide some useful service early; then incorporate progressively more advanced satellites when replacements and additions become necessary or possible, and use more advanced launch vehicles.

This kind of action could allow progress in the directions indicated by experience and could tend to avoid serious consequences that might follow from a full commitment to either a stationary or a nonstationary system. For with the nonstationary system, whatever its short-term attractions, there may be awkward and expensive problems of long-term growth. And with the stationary system, there may be unforeseen difficulties in achieving sufficient satellite reliability, with the result that an operational communications system would be long delayed.

In the longer run, as larger satellites with greater power and reliability become available, it should be possible to provide superior communication services to quite small and simple terminal equipment such as might be suitable for use by small military units in the field or installed in aircraft.

IV. OBSERVATION SATELLITES

The possibility of photography from satellites can be thought of as an extension of photography from airplanes. It can be used as an instrument of reconnaissance or surveillance for defense purposes. It can also be used for many economic purposes.

Observation from satellites is of interest because, due to the great speed and altitude of the vehicle, very large areas can be covered rapidly. The major reason for specific interest in photographic techniques for use in satellites is the quality image available from photography.

An important parameter in describing the performance of observation systems is resolution.

As used originally by astronomers, "resolution" described the ability of a telescope to separate and make perceptible the two individual parts of a double star. As it has come to be applied over the years to photographic systems, resolution refers to the ability to render barely distinguishable a standard pattern consisting of black and white lines. When we say the resolution of a system is 10 lines per millimeter, we mean that the pattern whose line-plus-space width is 0.1 millimeter is barely resolved or distinguished, that finer patterns are not perceived, and that coarser patterns are more clearly seen.

Ground resolution is a familiar term in all discussions of observation-satellite performance. It is simply the ground dimension equivalent to one line at the limit of resolution.

Many factors enter into assessment of the interpretability of an aerial photograph. Resolution is only one, but an important one.

The ground resolution of a high-quality photographic system in a satellite may be of the order of, say, 5 to 100 feet, from altitudes of 300 miles.

Mapping photography during World War II which was taken at an altitude of 30,000 feet secured a ground resolution of perhaps 15 to 20 feet. Thus, satellite performance possibilities are quite acceptable in these terms.

I have already mentioned the possibility of using satellites for observation within the hemisphere specifically for defense purposes. Such devices also can provide valuable service in supplementing aerial photography for economic and other functions.

Successful application of aerial photography to the many economic problems depends, first, upon the large view afforded, and, second, upon the recording of fine enough detail to permit accurate identification, measurement, and comparison.

Satellites can yield a grander view, a larger perspective than we have ever attained before. Photographs from rockets at altitudes of 150 miles have already yielded spectacular views. The possibility of seeing, as a whole, relationships, formations, and terrain features which require the perspective of distance is an exciting prospect. The world today is still poorly mapped, its resources and far reaches still not measured.

Ice and snow surveys over vast areas, iceberg patrol, and studies of ocean wave propagation all require the coverage of large areas, which is impossible to accomplish by means of conventional airborne observation systems.

It may be that routine large-area observation of snow accumulation and glacier movements could, for example, help in giving timely warning of slide disasters of the sort that recently caused such tragedy in Chile.

The Western Hemisphere includes a number of major river systems of great economic importance. Large-area observation of these river systems and their tributary sources could be of considerable value in predicting conditions on these rivers, including flood warnings, and such photographic coverage should be of great value in future large-scale engineering programs of river improvement and exploitation.

Satellite photography can cover large areas to supplement the wide use of aerial photographs in obtaining geologic information. Geologic interpretation of aerial photographs is based on recognition of photographic tone, color, texture, pattern, relation of associated features, shape, and size.

In petroleum exploration aerial photographs provide a wealth of information primarily with regard to potential structural traps. Examination of such features as stream patterns are useful--anomalous stream characteristics may suggest interesting subsurface structures.

Aerial-photo interpretation can suggest faults and thus be helpful in ore-deposit studies.

Analysis of soil patterns yields information regarding permeability of surface materials that are of concern to the engineering geologist.

For work in agriculture, an aerial photograph by itself without even the most simple instrument offers many advantages for certain types of activity. This is so because an aerial photograph records an almost

infinite amount of data concerning the earth's surface and those things immediately upon it. It provides a person with a picture showing a multitude of things that could not possibly be delineated on a conventional map of the same area. If we go a step further and provide these people with a stereoscope and the training necessary to use it properly, we magnify the usefulness of an aerial photograph many times.

The United States Soil Conservation Service from its very inception, some 25 years or so ago, has used aerial photography and photogrammetry on a large scale. The first very large aerial surveys that were made in the United States were made by SCS back in 1934, 1935, and 1936, when a number of large areas were photographed, and controlled mosaics were compiled on several projects. One of the larger jobs was the Dust Bowl aerial survey in the southwestern United States. This covered some 68,500 square miles. At that time, there was no one aerial survey contractor big enough to handle that job; it was necessary for three contractors to get together to bid on it.

In recent years it has not been necessary for the SCS to contract for large aerial-survey projects, since the extensive photo coverage of the Commodity Stabilization Service is available for general use. Although the contracts for aerial surveys have thereby dropped off materially, the use of aerial photography and simple photogrammetric procedures has increased tremendously.

The SCS now cooperates with the farmers and ranchers in more than 2800 soil-conservation districts and several hundred other work projects. One of the very first actions of SCS when a new soil-conservation district or other project comes into being is to see that it is furnished with appropriate aerial photographs for all of the technicians who will

be operating on that job.

To make these aerial photographs most useful for its technicians the SCS has for a good many years been conducting training sessions on the use of a simple stereoscope and basic photo-interpretation procedures which will be of most help to those technicians. The training given these men is of the very simplest kind. There is no intention of making photogrammetrists or cartographers out of them. They are taught how to orient the photographs and how to use a stereoscope and are given enough practice so they gain sufficient skill to proceed on their own initiative after they go back to the field. These training sessions are confined to rather small groups so that personal attention can be given each and every man. In this way, practically everyone is able to see stereoscopically and have some idea about how those photographs can be of help to them in their occupations.

While the SCS restricts its training of field technicians to the most simple aspects of photogrammetry, the usefulness of photogrammetric techniques in more complicated jobs is also explained. This is done so they will recognize problems that are beyond their depth and will know that they can call on a cartographic unit for help in situations that require complex equipment and highly specialized personnel.

The SCS employs a great number of soil scientists--about a thousand of them--for the purpose of making an inventory of the lands to a depth significant in agriculture. All of these scientists use simple photo-interpretation techniques every day. They use the photographs in the office and in the field. Under some circumstances, they may study mosaics or photo-index sheets for simply determining broad soil- and land-use relationships. For their detailed soil surveys

they will use pairs of vertical aerial photographs along with a stereoscope for studying land forms, vegetation, tone, texture, and other significant features. A soil survey cannot be made entirely by photo-interpretation techniques. A soil scientist needs to feel the soil; he must make borings and chemical analyses of the various soils. He does, however, use photo-interpretation techniques as an extremely helpful aid. He can study the aerial photographs stereoscopically and tentatively delineate points where slopes break, vegetation changes, tones or other significant relationships appear. To be successful, he must learn local associations; he must obtain knowledge of the relationship of a particular soil to the local terrain, to slope, elevation, drainage, tone, vegetation, and many other things. With that knowledge, he can go a long way in making tentative delineations of soils on aerial photographs, with the use of a stereoscope.

The SCS has found that soil scientists can more accurately record the soil survey on photographs of the appropriate scale when they use a stereoscope. They can also match the survey from one photograph to the next faster and more accurately. They can review and study their work or that done by someone else. The use of a stereoscope permits the study of specific areas for the purpose of discussion. For example, a soil scientist and his supervisor can in many instances very easily sit down and discuss an area more satisfactorily after each has made a careful stereoscopic study of the area in question. They often find that the use of a stereoscope is very well adapted to making spot checks of soil-survey work.

A soil scientist who is very familiar with an area and skilled in noting the relationships between soils of the area and their appearance

on the photographs can do a very effective job with nothing more than a simple pocket stereoscope, good photos, and a good understanding of their limitations. In general, he has no need for complicated equipment.

The conservation farm planner works directly with a farmer in advising him on the planning, location, and installation of various conservation practices. He aids the farmer or rancher in developing a conservation plan for the farm or ranch which will not only conserve the soil and water resources but will fit into the farmer's or rancher's wishes, needs, and capabilities. These conservation farm planners can do a much better job if they can get a third-dimension view of the particular farm they are planning. It gives them some idea of where the problem areas are located and enables them to more easily and intelligently discuss the whole farm and its problems with the farmer or rancher. The farm planner can point out sites where a farm pond might well be located. He can very quickly run out the watershed above any such location to determine the capacity and the design criteria for that small farm pond. He can, at the same time, gain some idea concerning the arrangement of terraces and other water-disposal areas.

It is true that he could get this information and lay out a farm plan equally well with ground methods. However, it would take him quite a long time to travel the farm and make such surveys as would give him information he could obtain in just a few minutes by studying the area under a stereoscope.

The agronomist who is interested in plant life can use aerial photographs and a stereoscope to very good advantage in studying vegetative patterns which are of significance to him. He will often use the

photos for the same purpose as the farm-planning technician. He can quickly study the present land use of the farm, field layouts, arrangement of the roads, farm buildings, streams, etc., on which, among other things, he can base certain recommendations.

The biologist, too, uses aerial photographs to a great extent in the SCS. He can locate present wildlife cover and study areas that are potentially subject to further development. For example, he can locate and determine the extent of low-lying lands, small waste areas, ponds, and many other features which are now or may in the future be developed into suitable areas for various wildlife habitats. The biologist, like the farm planner, is also interested in reviewing the over-all farm layout. The arrangement of the roads, fields, buildings, drainage, low spots, etc., are things that are of very great importance to him in making recommendations to the farmer or the conservationist.

The engineers and engineering aides in the SCS number in the many hundreds. The SCS has always had difficulty getting and keeping enough engineers to satisfy its needs. It has, therefore, always been quite important that ways be found of making the jobs easier for these men so that their skills may be spread over a greater area. Simple photogrammetric techniques are quite useful to the engineer. He can tentatively lay out lines of traverse, levels, etc., taking advantage of the most easily traveled routes that will provide the required data to the necessary degree of accuracy. He can very easily select pond sites, study the cross section of a valley, and run out a watershed to a degree of accuracy sufficient for these farm types of engineering operations.

In the small-watershed program, which is administered by the SCS, the technicians find simple photogrammetric techniques to be most effective. These small watersheds vary from 2000 to 200,000 acres in extent. Each of these projects must be studied in detail by engineers, hydrologists, agronomists, soil scientists, economists, biologists, and geologists. Much of their work can be done most easily and accurately by using aerial photographs with a simple stereoscope. The engineers can, for example, tentatively locate all of the potential water-detention-structure sites in the whole area within a few hours. They can establish, on an approximate basis, the capacity of each and the watershed above them. The economists can study the site to determine whether or not the area protected by a proposed structure will be worthwhile. They can also determine very quickly whether the impounded water behind a structure placed at that point would be apt to inundate valuable or worthless property. In other words, they can see that inundating the land either will or will not submerge buildings, roads, valuable farm lands, etc. The hydrologists can cruise the area quickly with a stereoscope and study stream-channel characteristics and other things of importance to them. The conservationists can study the present land-use pattern and develop plans for future land use which will tie in with the whole watershed-protection project.

Generally, more complex photogrammetric equipment is required only when it is necessary to run the topography on a number of reservoir areas which have been selected as being of potential value in the over-all watershed plan. This topographic work will be done by one of the SCS field cartographic unit offices if the areas are large

enough and if they are located where stereo-plotting instruments are practical.

A new kind of soil map will soon appear in the series of soil survey reports as a result of the combined efforts of the Department of Agriculture and state agencies working together on the National Cooperative Soil Survey. These maps will have an aerial photomosaic background with soil boundaries and symbols overprinted in red.

Mapping of soils in the United States began in 1899. This continuing program has provided published maps for approximately 1700 areas since that time. The majority are now 25 or 30 years old and, therefore, represent what was known about the soils a quarter of a century or more ago.

In recent years there has been an increasing demand for larger-scale maps from which one can read accurately, in relation to local land lines, the kinds of soil in specific fields. Such maps are required for a variety of uses: farm and ranch planning in soil-conservation districts, research and education programs of the Department and the state colleges, planning the agricultural phase of such programs as the Tennessee Valley Authority and the Bureau of Reclamation, tax assessment, predicting engineering problems on new highway construction, and the location of certain road-building materials such as gravel, sand, and clay. For many other activities, such as the Soil Bank, the Great Plains program, and the Agricultural Conservation Program, detailed soil maps are needed on which individual fields may be recognized clearly.

To meet these demands, the cartographic division of the SCS made a comprehensive study of the economics of producing maps of sufficiently

large scale to meet the needs of all of these users. It was found that larger-scale maps with an aerial photographic mosaic background could be produced by modern cartographic methods for considerably less than the old-type, smaller-scale, colored maps. By using an aerial mosaic much drafting was eliminated, and at the same time a greater amount of background detail was included. The aerial mosaic shows such details as field boundaries, broad land use, minor roads or trails, and many others that could not be shown on a line base map.

In summary, aerial photography can be of extensive value in improving the agriculture structure of a nation and can permit ready application of modern soil-management techniques with a minimum demand on scarce trained people for time-consuming field work. If agriculture is to be greatly improved over very large regions in short order, photographs of vast areas will be needed on a wholesale basis--the capacity to do just that is available through satellite photography.

Satellites will never be able to match the ability of airplanes to take very detailed photographs. However, use of satellites for large-area coverage can free airplane resources for attention to problems requiring great detail.

V. WEATHER SERVICES

Nearly all human activities, and certainly those related to defense, have always been influenced to an important extent by weather; and substantial advantages can accrue to us from the possession of timely and accurate weather prediction.

It is now rather well established that satellites gathering meteorological data are entirely practical and can contribute greatly to the supply of such data by virtue of their ability to cover vast areas of the globe in short times.

The benefits to be gained from observing weather phenomena from outside the earth's atmosphere have long been apparent to meteorologists, who have been limited by the fact that weather data from surface observation in sufficient detail were obtainable from only about 10 per cent of the world. The other 90 per cent was so sparsely inhabited or seldom visited that detailed and accurate predictions for large areas for more than a few days in advance were nearly impossible.

National meteorological services were begun about 100 years ago, strengthened and enhanced by cooperative agreements of information exchange between many nations. But these were confined mostly to those nations and areas of the Northern Hemisphere and limited largely to Europe and the North American Continent. Two-thirds of the globe is water, and except for the North Atlantic and great-circle Pacific shipping tracks, from which daily reports from ocean vessels could be obtained, the rest of the ocean areas are relatively untraveled. Thus, until the advent of the TIROS satellites, large weather disturbances such as hurricanes and typhoons could often build up to maximum force

and not be discovered and tracked until just before they struck inhabited lands.

TIROS I through VI have produced about 130,000 photographs of the weather, of which about 115,000 have been usable in conjunction with data gathered by conventional means.

The TIROS satellites will be followed by the improved NIMBUS satellites which will be in almost polar orbits for better area coverage. They will also be controlled so their sensing equipment is always pointed toward the earth to produce useful data at all points in their orbits. Thus, by maintaining several NIMBUS satellites in orbit at all times, every portion of the globe can be under weather observation every 24 hours. It should be possible to arrange direct read-out of NIMBUS data over any local area with ground stations of moderate cost.

Based on the experiments already accomplished it is possible to now undertake the establishment of an operational meteorological-satellite system with every confidence of success. The system could become fully operational before the middle of this decade and could provide an extremely powerful complement to present observational networks. It would provide coverage of important geographic areas not now adequately observed. Furthermore, it would make available new types of meteorological observations which would improve our understanding of meteorological events.

I would like to call your attention here specifically to the fact that we are speaking of two distinct objectives: first, the gathering of data of immediate practical usefulness, such as storm detection, and second, the gathering of data for use in meteorological research to

better understand weather processes. While the immediate benefits of a practical nature can be very great indeed, it is likely that the most important long-term value will flow from the research possibilities that can lead to greatly improved methods of weather prediction and, eventually, to some measure of ability to modify the weather.

Man has been trying to influence the weather since long before recorded history; however, programs of investigation into weather processes and a search for methods of control were undertaken on a sound scientific basis only about 30 years ago.

Since that time, only modest progress has been achieved, especially in the field of cloud seeding to increase rainfall. At best, relatively long-term experimentation with silver iodide has established a statistical possibility of increasing rainfall over a given area about 15 per cent over the normal.

The principal difficulty confronting all weather-modification research is the sheer immensity of phenomena involving extremely dispersed and uncertain factors. Coupled with these conditions has been a lack of effective research tools and methods to investigate continuously global causes of weather conditions. Weather satellites are hopefully answers to these problems.

From the progressive development of analysis techniques for weather-satellite photographs and infrared data can come new knowledge of atmospheric variations from which are bred incipient weather and climatic changes. Weather control and modification can be most effective before both regional and local storms build up to tremendous energies beyond the capability of any conceivable technique to handle, and weather

satellites will be able to provide early alert to storm-breeding conditions.

We now have at hand a variety of theoretical tools, such as increasingly realistic mathematical models of the atmosphere; and we have the technical tools, such as electronic computers, with which to analyze complex equations and data dealing with the physical consequences of artificial disturbances in model atmospheres and thereby design meaningful experiments which might be conducted in nature. What is needed is an adequate supply of meteorological data.

The weather satellite can now fill a great gap in our research picture by providing these analytical tools with an enormous quantity of the data needed to go forward.

With the availability of volumes of observational data from satellites and techniques for analytical study of the atmosphere, opportunities for progress in meteorological research are now very great, far greater than at any time in the past.

It is also significant that through the use of vehicles to explore interplanetary space, we can now approach the really fundamental weather problem, which is not merely the local circulation of the atmosphere of the earth and its associated climatic and weather fluctuations but the over-all view of the relationships between the sun and earth as a gigantic thermodynamic system.

Observations already show clearly that the earth must be regarded as traveling in a real sense through the outer atmosphere of the sun. The whole might be regarded as a form of heat engine with the sun as source and the earth as receiver.

Development of an understanding of this gigantic machine may lead us to major findings in weather-control mechanisms.

In a basic research field such as weather modification we can make no schedule estimate--major practical consequences may be a long way off or they may come with startling rapidity.

In the meantime, we can be reasonably confident that weather satellites will make possible quite rapid improvements in weather-information service.

An important aspect of this subject is the gross difference between the situations in the Northern and Southern Hemispheres. Due to the influence of the earth's rotation, the world weather structure tends to be separated into two roughly independent parts at the equator. Therefore, while the complex of surface observation stations in the Northern Hemisphere is fairly well developed, the data from this complex have virtually no relevance to the Southern Hemisphere. The southern part of the Americas has very little opportunity for receiving good meteorological data from other sections of the Southern Hemisphere except Australia, the Union of South Africa, and, to some extent, Antarctica. Thus development of good forecasts is hampered quite severely even with good local data. Because of this circumstance, the world-wide coverage from weather satellites is quite likely to lead to much sharper improvements in weather services available to the Southern Hemisphere than to the Northern Hemisphere. The immediate improvement is likely to be in timely detection and tracking of major storms; the next, an improvement in general forecasting, will require providing local meteorological services with the

capability to use satellite data, which are rather different in character from conventional weather data.

In the future it should be possible to set up satellites that can provide some data on wind magnitudes from observations of average sea-state over an ocean area and also a measure of ocean surface temperature. Such data would also be of great value in providing superior weather service.

The present basis for world cooperation in weather-satellite research is rooted in the World Meteorological Organization, under whose auspices proposals for world cooperation in the exchange of weather information and forecasts were drafted and implemented.

The World Meteorological Organization is a specialized agency of the United Nations and has been in existence since 1950. Actually, it evolved from the International Meteorological Organization which was established in 1878. It is composed of members representing 113 states and territories and has the following purposes: To promote world-wide cooperation in the establishment of organized weather facilities; to set up methods for the prompt dissemination of information; the establishment of weather measurement and analysis standards; to foster weather research and training programs within and between nations; and to assist in the exchange of knowledge and experience gained in the application of weather information to such activities as communications, agriculture, soil erosion, and so forth.

The prospects for great improvements in weather service in the moderately near future appear quite good and suggest strong implications for hemisphere-defense activities, and also great advantages for economic areas such as civil aviation, agriculture, and recreation.

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These ideas on relations between space technology and hemisphere security--some solid and immediate, others rather tentative and distant--surely do not exhaust the subject. Further exploration of these and other possibilities should be interesting and useful. I am very anxious to hear your comments and expressions as guides to such further examination.

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